Conference Paper

Application of Ni-Mg-Ce Master Alloy Scrap for Inoculation of Copper-Nickel Alloys

R. K. Mysik, S. V. Brusnitsyn, and A. V. Sulitsin

Ural Federal University, 19 Mira street, Ekaterinburg, Russia, 620002

Abstract

The problems of production of copper-nicckel alloys ingots by semicontinuous casting method are analysed. The requirement of grain size refinement in cast alloys macrostructure is shown. It is necessary to reduce the probability of hot cracks formation and increase the fabricability of cast bars during plastic working. The reasonability of fine fraction of Ni-Mg-Ce master alloy application for inoculation of copper-nickel alloys is established. The results of laboratory experiments on the study of master alloy quantity influence the structure and hardness of Cu-5Ni-1Fe, Cu-10Ni-1Fe-1Mn and Cu-30Ni-1Fe-1Mn copper-nickel alloys are presented. On the basis of industrial experiments it is revealed that inoculation of Cu-5Ni-Fe alloy ingots of diameter 200 mm by Ni-Mg-Ce master alloy leads to considerable reducing of macrograin size. It allows to improve mechanical properties of ingots and ensure their uniform distribution in cross section of ingots. It is established that residual magnesium content in alloy must be in range from 0,02 to 0,06 wt. %. The use of Ni-Mg-Ce master alloy makes it possible to increase the processability of copper-nickel alloys during plastic working and utilize the fine fraction master alloy scrap inevitably formed during its production.

Keywords: Copper-nickel alloys, Semicontinuos casting, Ingot, Inoculation, Ni-Mg-Ce master alloy, Structure, Mechanical properties

Corresponding Author: R. K. Mysik; email: kafedralp@mail.ru

Received: 6 June 2017
Accepted: 9 July 2017
Published: 24 August 2017

Publishing services provided by Knowledge E

Selection and Selection and Peer-review under the responsibility of the Technogen Conference Committee.

1. Intorduction

At present wrought copper-nickel alloys are widely used in various industries. Some are used for manufacturing of high-duty tubes for heat exchangers in shipbuilding and atomic industry. Therefore high specifications for chemical composition, mechanical properties, corrosion resistance and cavitation resistance of this alloys must be carry out [1]. Copper-nickel alloys are melted in the cored induction furnace. Ingots are poured in the water-cooled crystallizer by semicontinuous casting method. The competitiveness of these alloys production is determined not only by its quality, but also by its value. Recently the percentage of scrap and waste with increased sulfur content in the composition of charge materials has increased. Sulfur is undesirable impurity in copper-nickel alloys. It forms eutectic with copper and nickel. The eutectic locates along grain boundary, slacks grain boundary and makes for ingots cracking during plastic working. Traditionally a carbon black is used as melt cover in crystallizer. A carbon black has low heat conductivity. This fact leads to high temperature difference between central zones and surface of ingot. The temperature difference can reach value of 700°C leaving the crystallizer. It makes for arising of thermal stresses and forming cracks in the central zones of ingot [2–4]. It is known that the grain refinement is an effective method of effort to hot cracks formation. Moreower the equiaxial fine-grained ingot structure is preferable for plastic working. Basic methods of ingots structure reducing are vibration, electromagnetic exposure and addition of modifier and inoculators in the melt. The addition of modifier is the most reasonable and practically feasible method of ingots structure reducing.

Magnesium is one of modifiers for copper-nickel alloys. It neutralizes harmful effect of sulphur due to magnesium sulfide MgS formation. Moreover use of magnesium provides effective deoxidizing of copper-nickel alloys due to magnesium affinity for oxygen [5]. The formed particles of MgO may be additional centers of crystallization. However addition metallic magnesium in the melt of copper-nickel alloys is difficult because of low density and low boiling temperature of magnesium. Therefore it is appropriate that magnesium will be added in the melt as a component of master alloy.

The heavy Ni-Mg-Ce master alloy is used for high-strength cast iron producing. The master alloy is supplied in pieces of 20…110 mm in size. The master alloy ingots are crushed. This produces a large quantity of fine fraction. In the process of this fraction remelting there is significant loss of metal with slag. To reduce the amount of irrecoverable losses it is necessary to search for alternative spheres of fine fraction of Ni-Mg-Ce master alloy application. So long as nickel is main alloying element in copper-nickel alloys the one of variants of master alloy fine fraction application is its use as modifier for copper-nickel alloys during ingots casting.

In this article the problem of identification of influence of Ni-Mg-Ce master alloy addition on structure and mechanical properties of copper-nickel alloys is posed. To achieve the assigned aim the series of experiments on inoculation of Cu-5Ni-1Fe, Cu-10Ni-1Fe-1Mn and Cu-30Ni-1Fe-1Mn by Ni-Mg-Ce master alloy was carried out. The master alloy had following chemical composition (wt. %): 84 Ni, 15,5 Mg, 0,5 Ce. Cerium as magnesium reacts with oxygen and sulphur. As result high-melting compaunds particles are formed. This particles are additional solidification centers and favour cast alloys grains reducing.

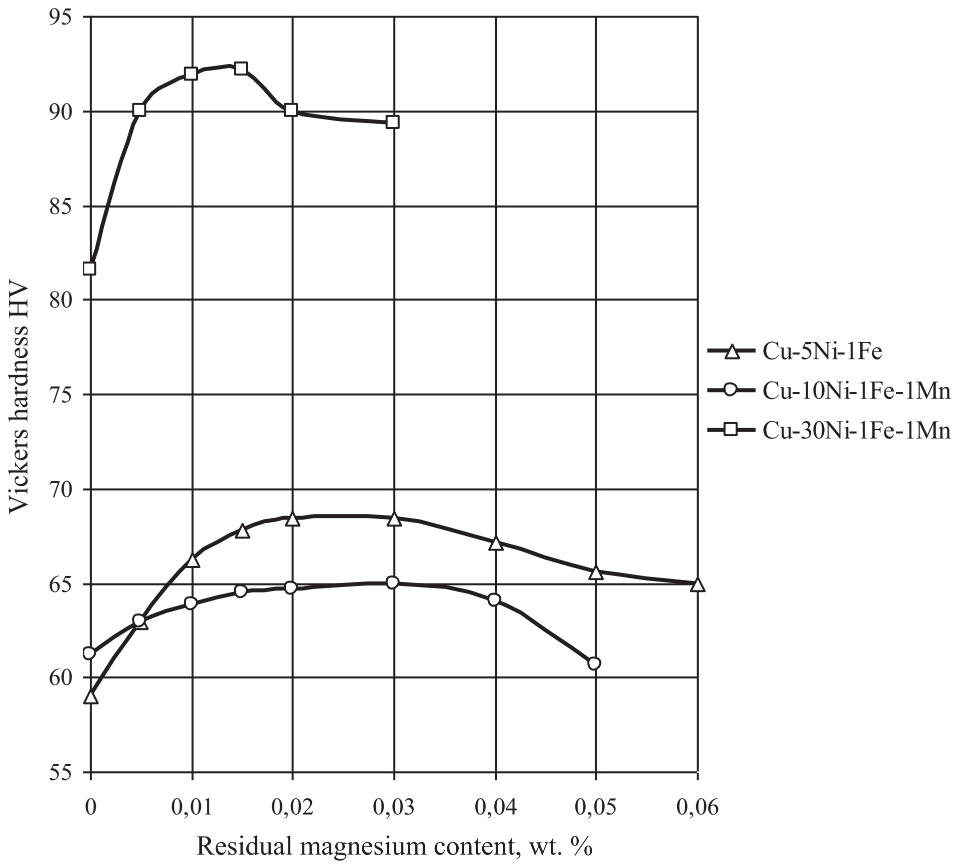

Figure 1: The relationship between Vickers hardness and residual magnesium content.

2. Results and Discussion

Alloys were melted in the cored induction furnace with the charcoal on the melt surface. The melt was took in the graphit-chamotte crucible. Ni-Mg-Ce master alloy was added in melt at the rate 0,01...0,2 % of magnesium based on the melt weight. The melt in the crucible was blended and poured in the steel casting mold. Ingots had diameter of 40 mm and height of 100 mm. For metallographic analysis and residual magnesium content determination ingots were cuted to obtain samples. The influence of Ni-Mg-Ce master alloy additions was evaluated on the basis of average grain area change. The results of experiments are presented in Table 1.

The metallographic analysis of alloys Cu-5Ni-1Fe, Cu-10Ni-1Fe-1Mn, Cu-30Ni-1Fe-1Mn samples has shown that Ni-Mg-Ce master alloy addition leads to effective grain reduce in the alloys structure.

Moreover the hardness of copper-nickel alloys samples was determined. The relationship between Vickers hardness and residual magnesium content is shown at Figure 1.

Alloy	Residual magnesium content [wt. %]	Average grain area [mm^2]
Cu-5Ni-1Fe	Unmodified	18,710
	0,010	4,740
	0,018	0,580
	0,019	0,500
	0,030	0,250
	0,060	0,130
Cu-10Ni-1Fe-1Mn	Unmodified	15,470
	0,006	5,550
	0,011	3,820
	0,021	3,300
	0,022	3,160
	0,035	1,880
	0,053	1,890
Cu-30Ni-1Fe-1Mn	Unmodified	3,333
	0,006	0,300
	0,014	0,370
	0,021	0,294
	0,031	0,020

Table 1: Change in average grain area in the structure of copper-nickel alloys depending on residual magnesium content.

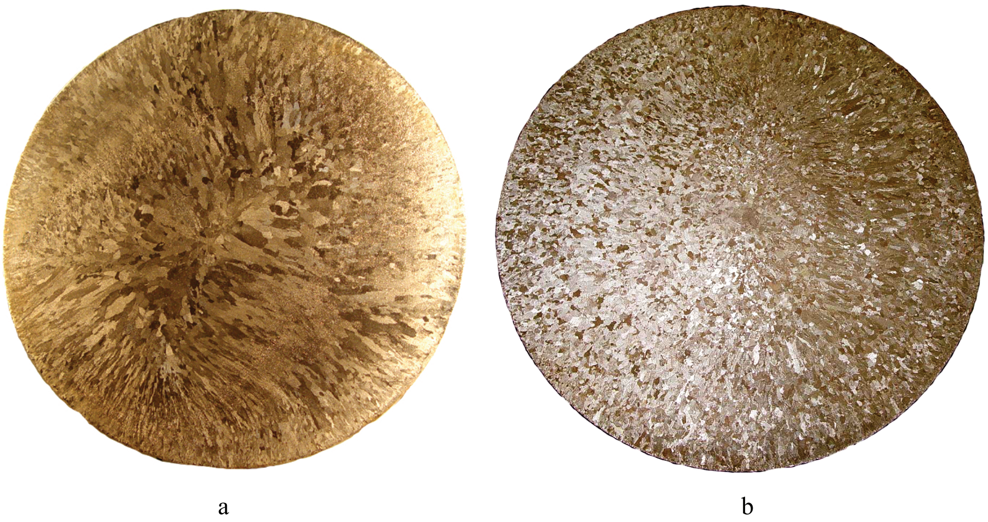

Figure 2: The macrostructure of Cu-5Ni-1Fe alloy ingots with diameter of 200 mm: a – standard casting technology; b – casting technology using inoculation.

It is established that copper-nickel alloys Cu-5Ni-1Fe and Cu-10Ni-1Fe-1Mn have a maximum Vickers hardness in case of residual magnesium content in the range from 0,02 to 0,04 wt. %. The alloy Cu-30Ni-1Fe-1Mn has a maximum hardness in case of magnesium content 0,008...0,012 wt. %.

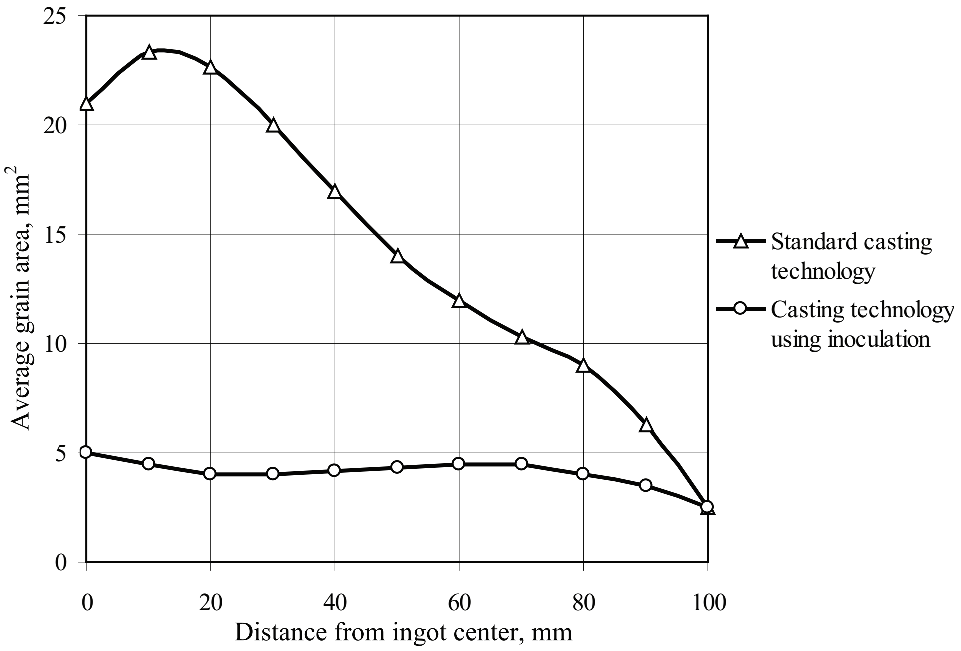

Figure 3: The change in average grain area along radius of Cu-5Ni-1Fe alloy ingot with diameter of 200 mm.

Despite the fact that influence of Ni-Mg-Ce master alloy addition on hardness of copper-nickel alloys was estimated on the basis of residual magnesium content one can not ignore effect of cerium. Probably in the alloy there is α-solid solution hardening. In case of residual Mg content exceeds 0.03% the hardness decreases because binding energy of grain boundaries is decreased. This fact leads to decrease in the hardness of alloys [6].

On the basis of laboratory experiments results the industrial experiments on inoculation of Cu-5Ni-1Fe alloy with use fine fraction of Ni-Mg-Ce master alloy during semicontinuous casting of ingots with diameter of 200 mm were caried out. The master alloy was added in melt at the rate of 0,35 wt. %. At the same time the residual magnesium content was 0,035 wt. %. The macrostructure of standard ingots and ingots produced using inoculation is shown at Figure 2. Results of metallographic analysis of ingots macrostructure are shown at Figure 3.

The analysis of ingots macrostructure shown that alloy inoculation using Ni-Mg-Ce master alloy the significant decrease of average grain area is observed. In this case the average grain area is practically unchanged along ingot radius. This structure provides even distribution of mechanical properties in the cross section of ingot. It is corraborated by results of mechanical tests of samples cuted from ingots (see Table 2).

Casting technology variant	Mechanical properties					
	Tensile stregth [MPa]			Elongation [%]		
	Ingot center	1/2 R	Ingot surface	Ingot center	1/2 R	Ingot surface
Standard technology	219	247	235	30	34	29
Technology using inoculation	242	248	247	35	34,5	32

Table 2: Mechanical properties of Cu-5Ni-1Fe alloy ingots samples.

It is seen that ingots poured using inoculation have higher strength and plastic properties. At the same time values of properties have a slight variation in the cross section of ingots.

3. Summary

The results of experiments made it possible to draw a conclusion about reasonability of using a fine fraction of Ni-Mg-Ce master alloy as a modifying additive for copper-nickel alloys. At the same time that residual magnesium content in alloy must be in range from 0,02 to 0,06 wt. %. The use of Ni-Mg-Ce master alloy makes it possible to increase the fabricability of copper-nickel alloys during plastic working and utilize the fine fraction master alloy scrap inevitably formed during its production.

References

[1] N. S. Arsent'eva, E. A. Kazantsev, A. V. Sulitsin, L. M. Zheleznyak, L. N. Marushchak, and O. L. Glukhova, “Technology for making welding wire from different alloys at the Kamensk-Ural'skii Nonferrous Metals Processing Plant,” Metallurgist, vol. 52, no. 3-4, pp. 192–196, 2008.

[2] S. Zhang, K. Song, X. Guo, Y. Zhang, and X. Li, “Corrosion behavior of B10 copper-nickel alloy pipe in flowing artificial seawater,” Tezhong Zhuzao Ji Youse Hejin/Special Casting and Nonferrous Alloys, vol. 36, no. 6, pp. 669–672, 2016.

[3] M. Metikoš-Huković, R. Babić, I. Škugor Rončević, and Z. Grubač, “Corrosion resistance of copper–nickel alloy under fluid jet impingement,” Desalination, vol. 276, no. 1-3, pp. 228–232, 2011.

[4] P. Sakiewicz, R. Nowosielski, and R. Babilas, “Production aspects of inhomogeneous hot deformation in as-cast CuNi25 alloy,” Indian Journal of Engineering and Materials Sciences, vol. 22, no. 4, pp. 389–398, 2015.

[5] A. V. Sulitsin, D. D. Lashchenko, R. K. Mysik, and S. V. Brusnitsyn, “Investigation of solidification process of coppernickel alloy mnzh5-1 (MHK5-1) round ingot during semi-continuous casting,” Non-ferrous Metals, vol. 2015, no. 2, pp. 71–74, 2015.

[6] A. M. Taher, “Effect of alloying elements on the hardness property of 90% copper-10% nickel alloy,” Materials Science Forum, vol. 872, pp. 13–17, 2016.

[7] X.-G. Dong, J. Zhou, Y.-Y. Yu, Y.-Y. Hu, and A.-J. Mo, “Influence of rare earth elements on mechanical properties and corrosion resistance of Cu-15Ni alloy,” Journal of Donghua University (English Edition), vol. 30, no. 3, pp. 249–253, 2013.